

Preliminary Results from the $K_L \rightarrow \pi^+ \pi^- \gamma$ Analysis

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KTeV Collaboration
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Overview

- $K_L \rightarrow \pi^+ \pi^- \gamma$ kaon momentum correction using $K_L \rightarrow \pi^+ \pi^- \pi^0$ background with 1 unreconstructed photon
- Preliminary fit results for g_{m1} , a_1/a_2 , and g_{e1}
 - Results include STATISTICAL ERRORS ONLY
 - Fit uses a preliminary momentum correction, based on HALF the complete data sample
 - g_{e1} result is presented as an upper limit
 - Plan is to show these numbers at SESAPS conference (Nov, 2003)
- Future Plans (systematics studies)

Kaon Momentum Correction

- Correction uses $K_L \rightarrow \pi^+ \pi^- \pi^0$ background in the 0.461 – 0.469 GeV mass region with 1 unreconstructed photon
 - Default kaon correction in MC is from $K_L \rightarrow \pi^+ \pi^-$ (no γ correction)
 - Reweighting with $K_L \rightarrow \pi^+ \pi^- \gamma$ signal events directly could bias results, since fit parameter values have been shown to alter the final kaon spectrum (due to acceptance effects)
- Cuts are virtually identical to signal event cuts, except for Pt2, PP0KINE, and $\pi^+ \pi^- \gamma$ mass

Kaon Momentum Correction (cont)

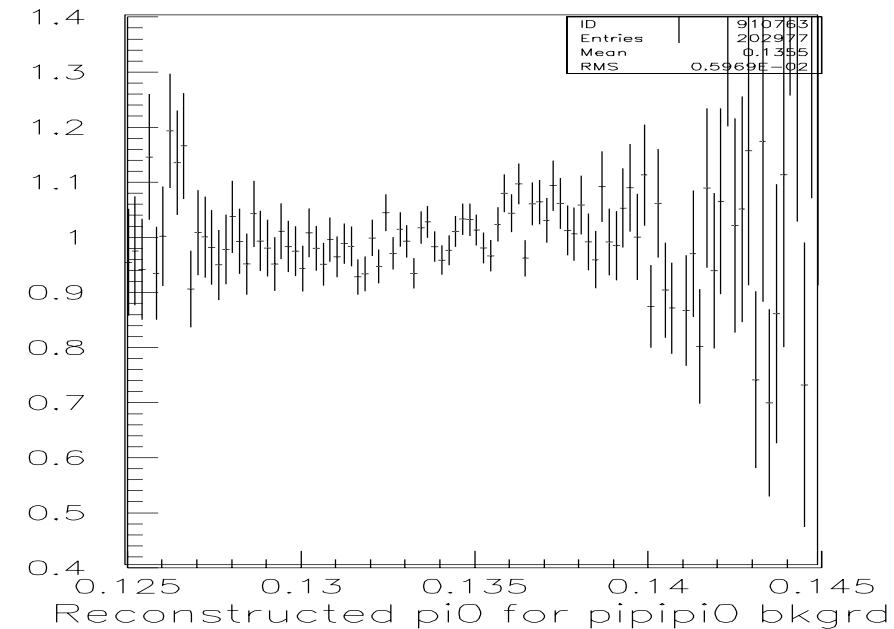
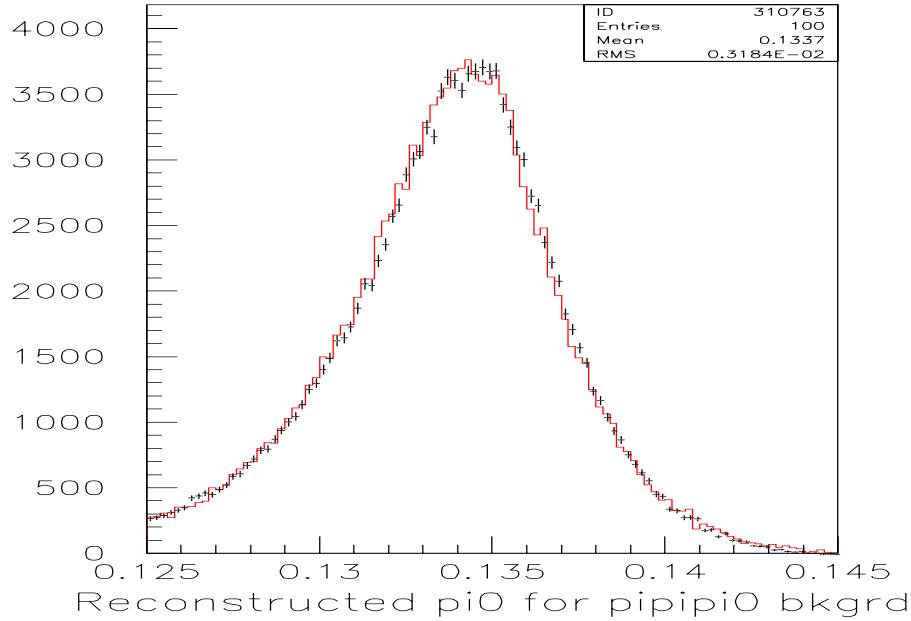
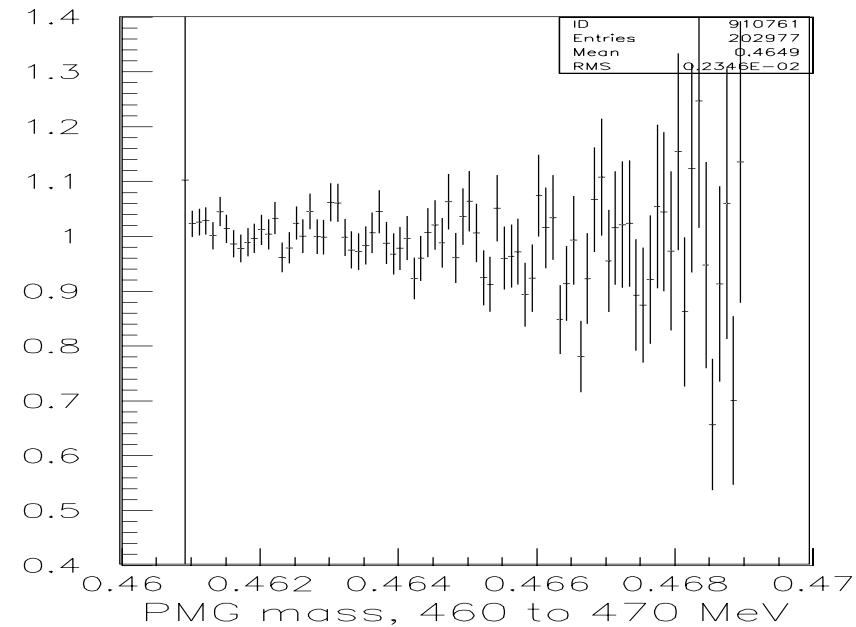
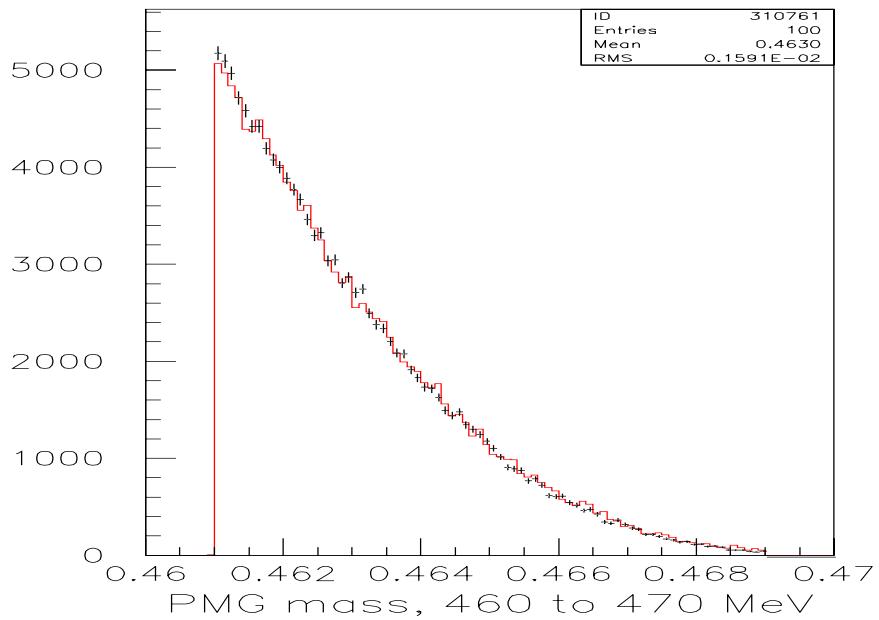
- Primary difficulty with this approach: $K_L \rightarrow \pi^+ \pi^- \gamma$ crunch does its job too well!!
 - Only about 130,000 events are in final 0.461-0.469 GeV mass region
 - We'd like to be accurate & produce a like number of $\pi^+ \pi^- \pi^0$ MC
 - This means generating a complete data-sized sample of $K_L \rightarrow \pi^+ \pi^- \pi^0$ monte carlo (**~7-8 billion events!!**) & running it through all L3 and crunch filters, etc
 - Since mid-August, we have successfully produced about HALF of a complete data sample (~70,000 final events)

Analysis cuts: $K_L \rightarrow \pi^+ \pi^- \pi^0$ background

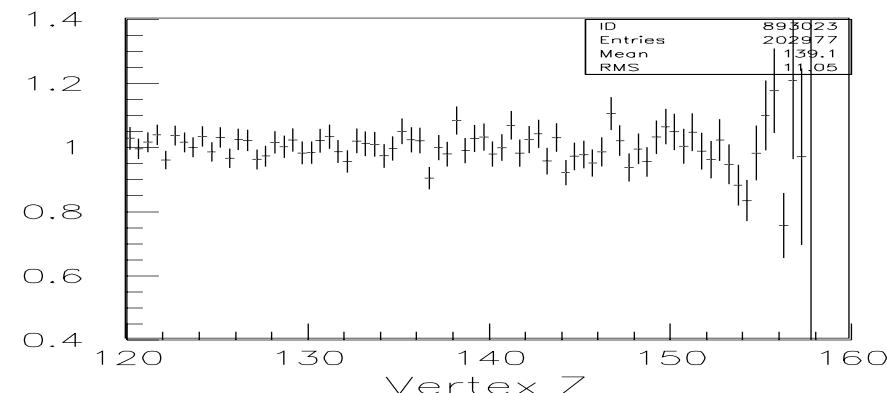
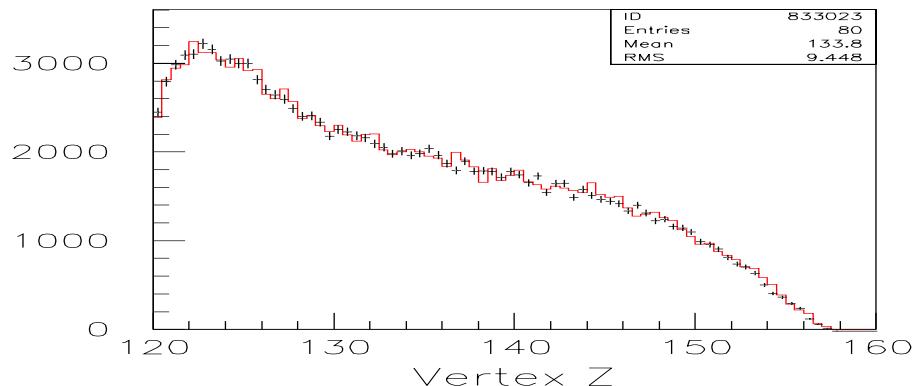
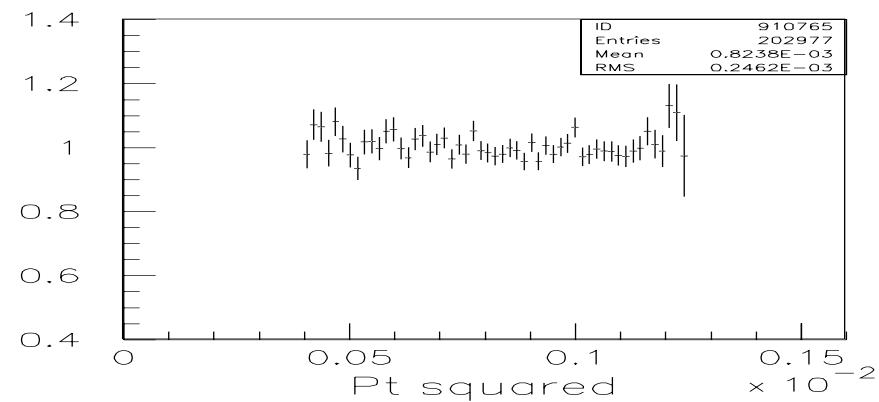
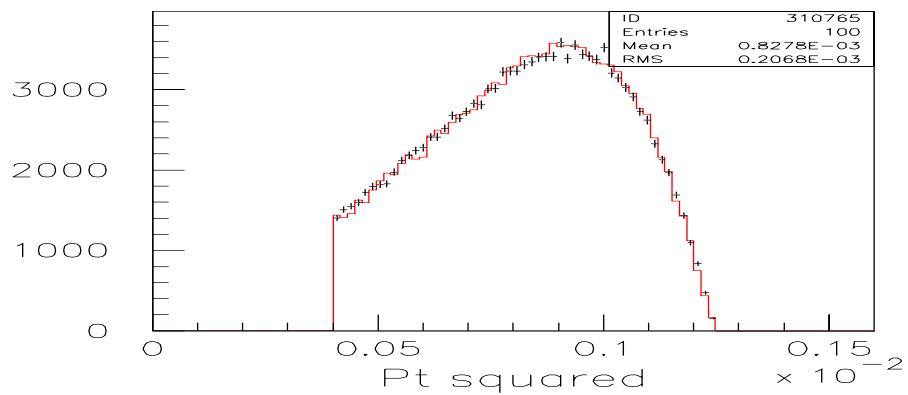
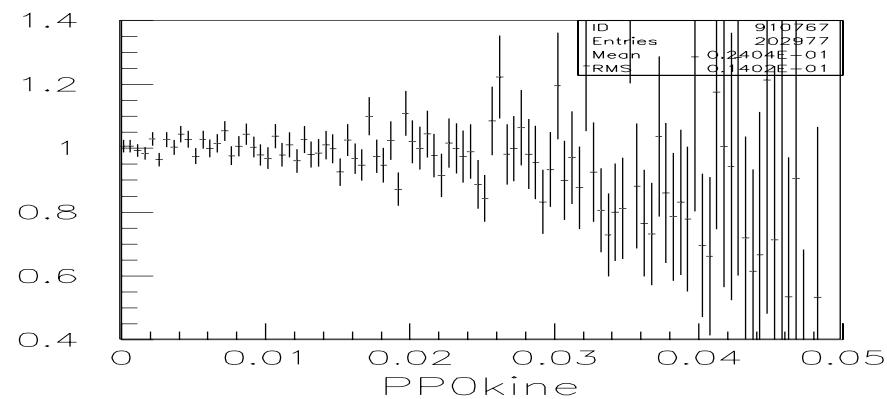
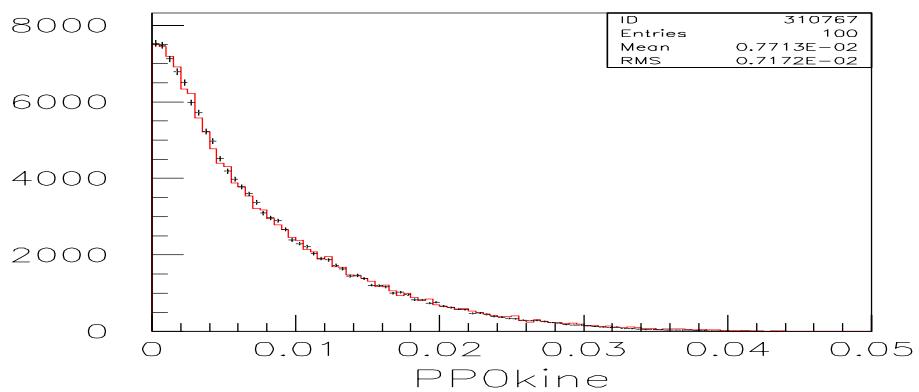
Criterion:

- Recon832
 - L1VER832
 - NTRKS
 - Clusters
 - Magnet offset χ^2
 - Vertex χ^2
 - Vertex Z
 - Track x-separation in CsI
 - Track momentum
 - π^+ - E/p
 - pp0kine
 - γ energy (Lab)
 - γ energy (Center of Mass)
 - γ -track separation in CsI
 - Fusion χ^2
 - γ CsI pipe block exclusion
 - γ CsI outer fiducial cut
 - $\pi^+ \pi^-$ invariant mass
 - $\pi^+ \pi^- \gamma$ momentum
 - $\pi^+ \pi^- \gamma P_T^2$
 - $\pi^+ \pi^- \gamma$ invariant mass
 - $\gamma \gamma$ mass cut at π^0 mass
- Event in sample if...
- Recon832 ok
 - istat $\neq 0$
 - NTRKS = 2
 - 1 or more non-track clusters
 - < 50
 - < 50
 - $120.0 < VTXZ < 158.0$
 - > 3 cm
 - > 8 GeV
 - < 0.85 GeV
 - > 0 GeV²
 - > 1.5 GeV
 - > 20 MeV
 - > 30 cm
 - < 48
 - smallring > 4.5 cm
 - seedring < 18.1 cm
 - < 0.492 GeV
 - $25.0 < P_{\pi^+ \pi^- \gamma} < 160.0$
 - < 0.0015 GeV²
 - $0.461 < M_{\pi^+ \pi^- \gamma} < 0.469$
 - $0.125 < M_{\gamma \gamma} < 0.145$

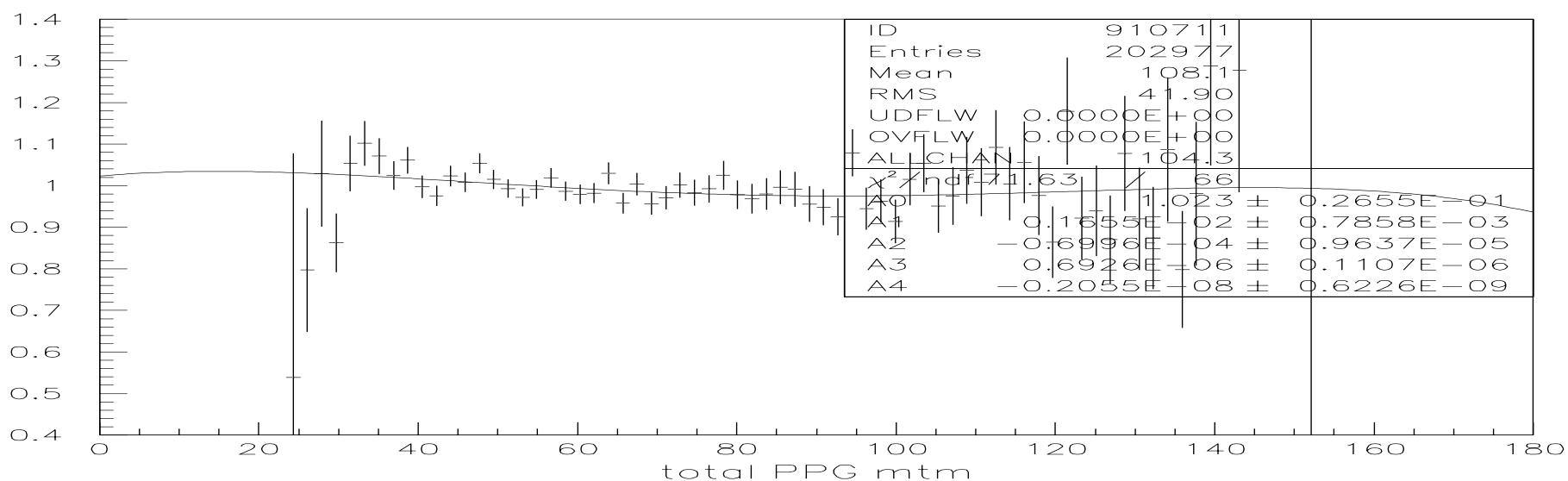
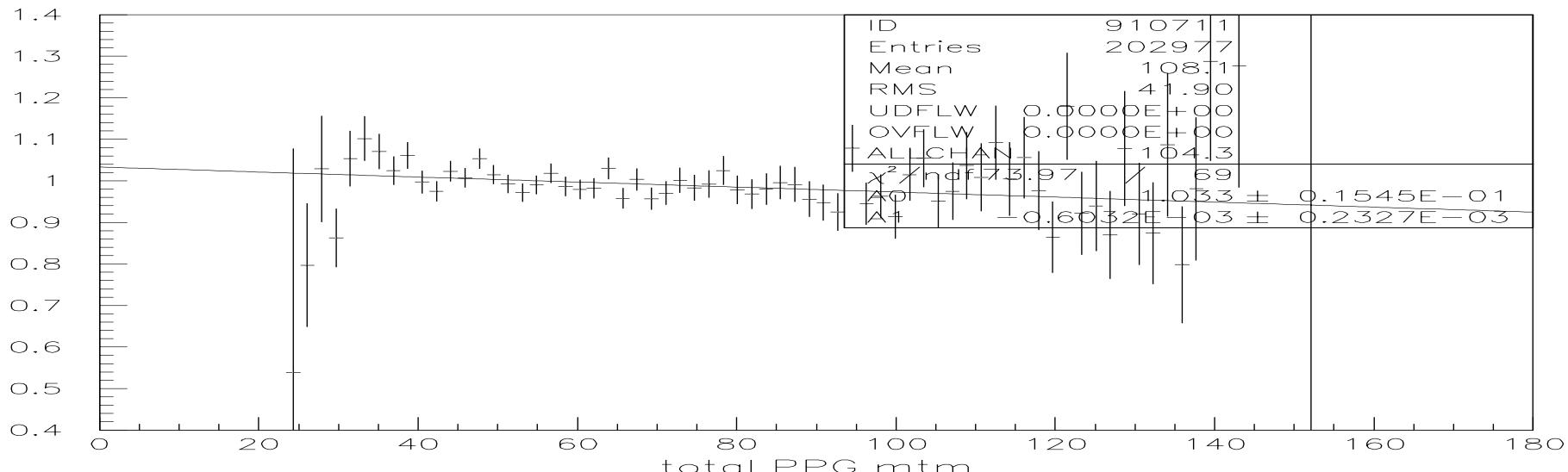
K_L → π⁺π⁻π⁰: Data / MC (461-469 MeV)



K_L → π⁺π⁻π⁰ : Data / MC (461-469 MeV)



$\pi^+ \pi^- \gamma$ Momentum: Linear and 4-D Polynomial best fits



$K_L \rightarrow \pi^+ \pi^- \gamma$ Preliminary Fit Results

- 3-parameter fit (ge1 assumed non-zero) (**STAT ONLY!**)
- $g_{m1} = 1.20 +/- 0.03$
 - $a_1/a_2 = -0.738 +/- 0.07$
 - $ge1 < 0.12$ (90% confidence)
- 2-parameter fit ($ge1 = 0$) (**STAT ONLY!**)
 - $g_{m1} = 1.19 +/- 0.03$
 - $a_1/a_2 = -0.740 +/- 0.07$

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- For comparison:
 - J. Belz, 1997 ($K_L \rightarrow \pi^+ \pi^- \gamma$) : $DE/(DE/IB) = 0.68 +/- 0.01$
 $a_1a_2 = -0.737 +/- 0.034$
 - UVa, 1997 ($K_L \rightarrow \pi^+ \pi^- e^+e^-$) : $gm1 = 1.35 +/- 0.17$
 $a_1/a_2 = -0.720 +/- 0.028$

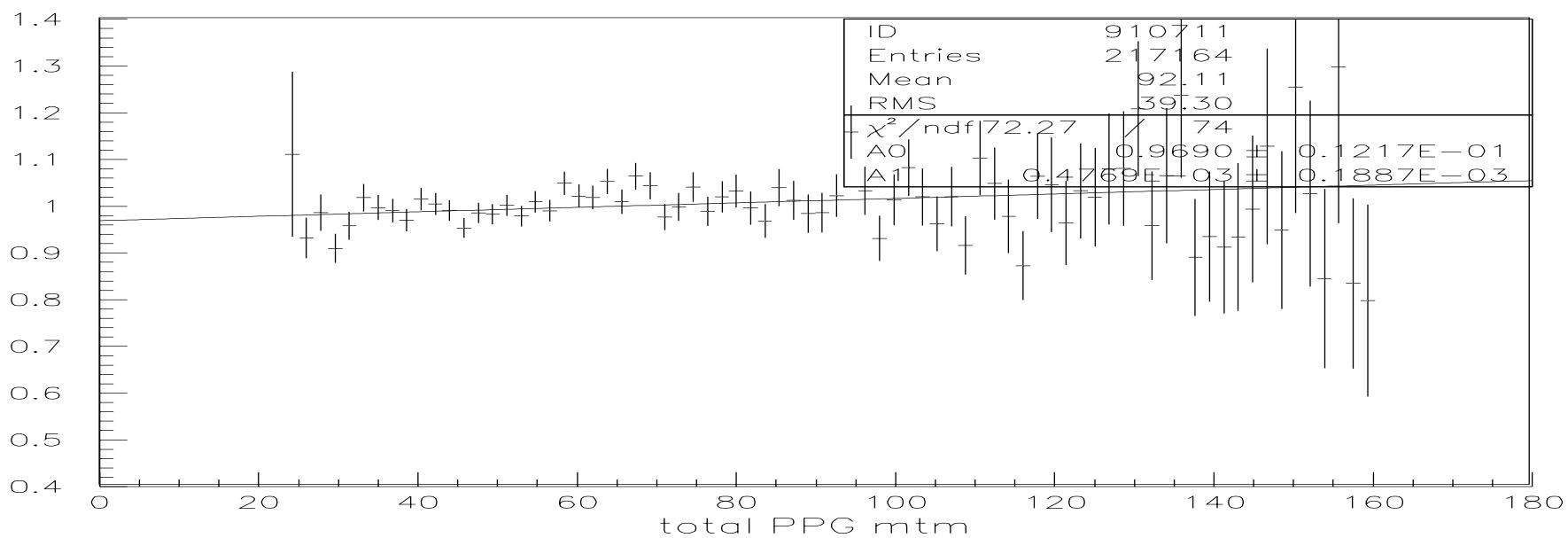
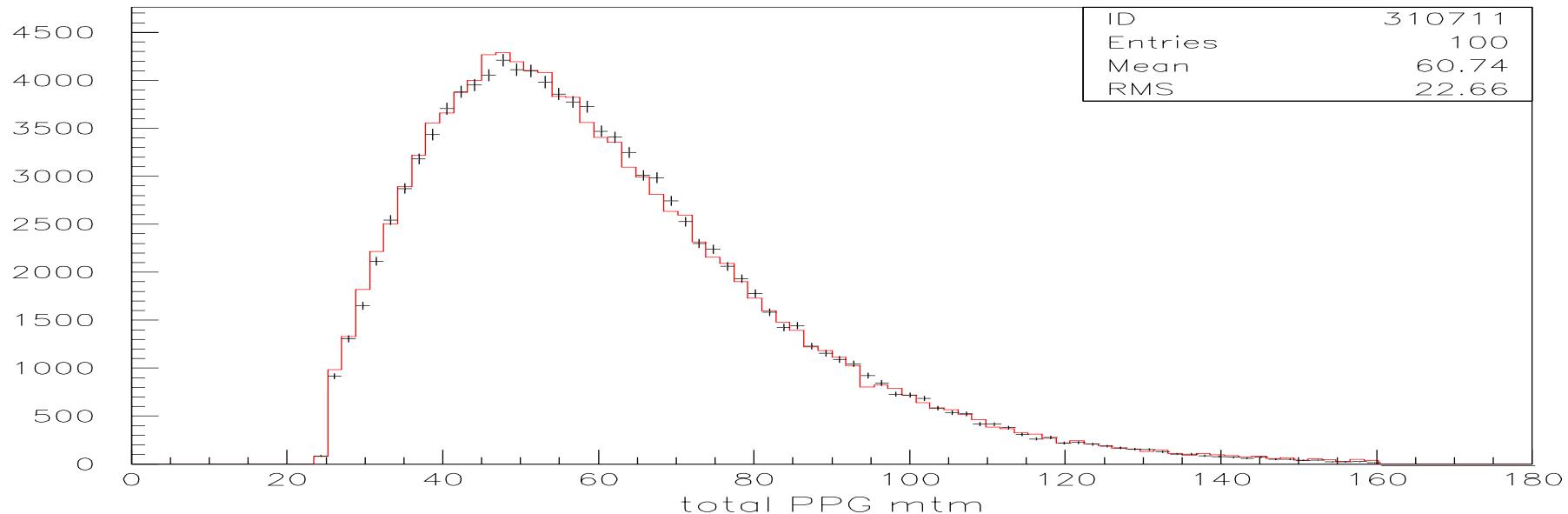
Analysis cuts: $K_L \rightarrow \pi^+ \pi^- \gamma$

Criterion:

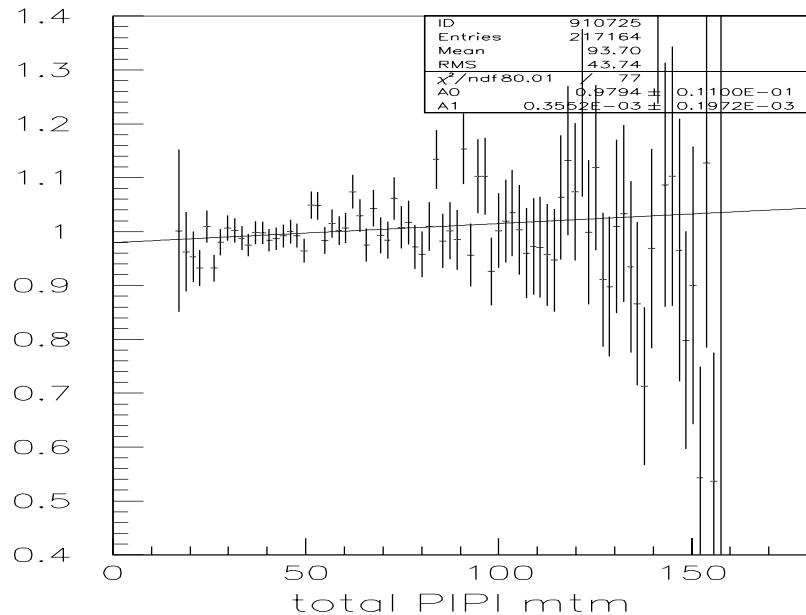
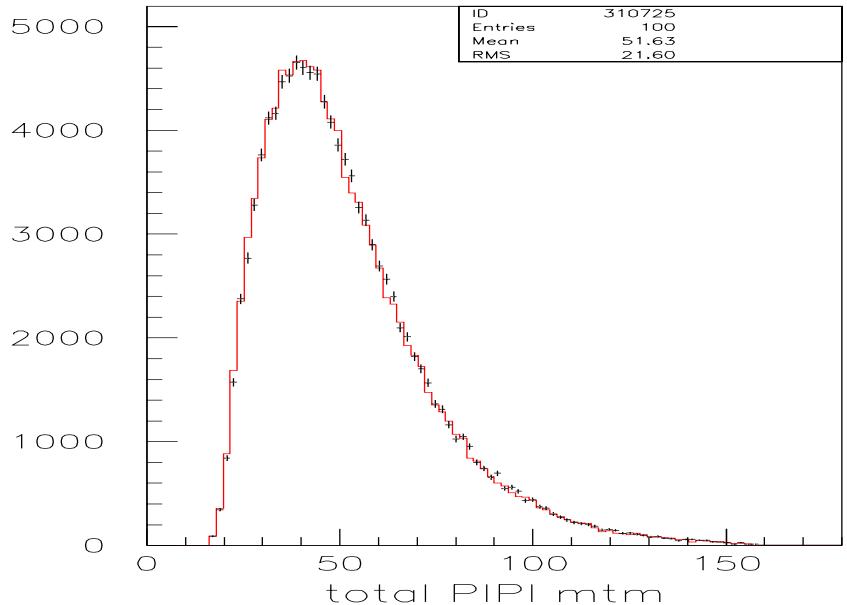
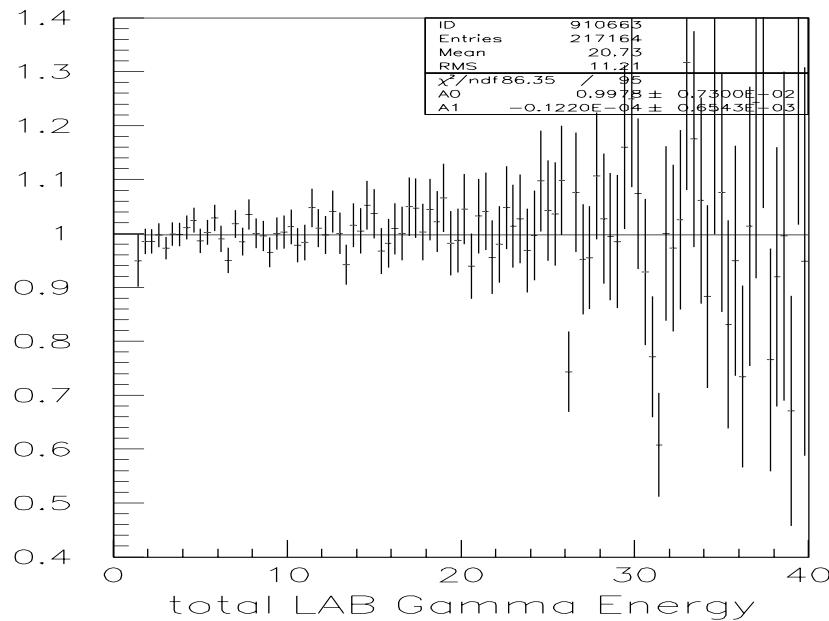
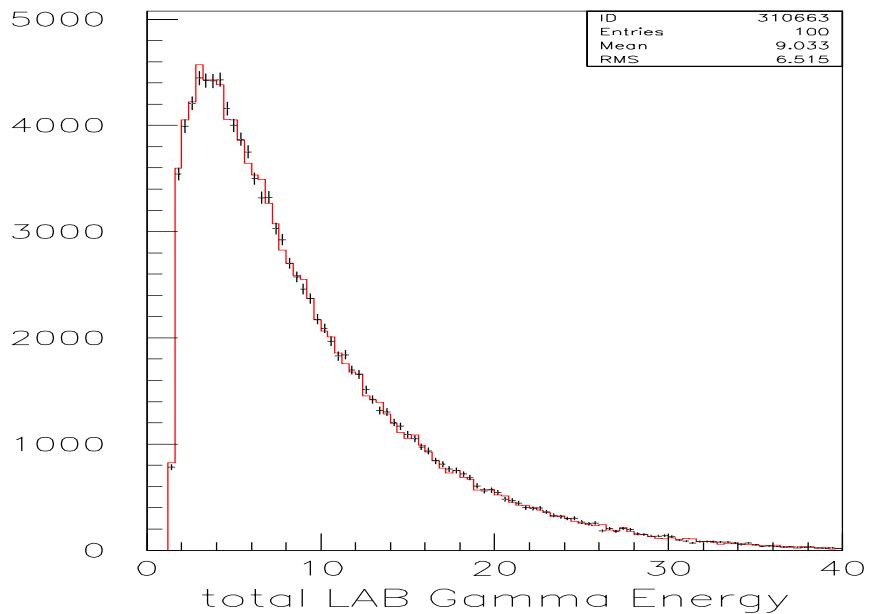
Event in sample if...

- | | |
|---------------------------------------|--|
| • Recon832 | Recon832 ok |
| • L1VER832 | istat \neq 0 |
| • NTRKS | NTRKS = 2 |
| • Clusters | 1 or more non-track clusters |
| • Magnet offset χ^2 | < 50 |
| • Vertex χ^2 | < 50 |
| • Vertex Z | $120.0 < VTXZ < 158.0$ |
| • Track X-separation in CsI | > 3 cm |
| • Track momentum | > 8 GeV |
| • π^+ E/p | < 0.85 GeV |
| • Pp0kine | < -0.0055 GeV ² |
| • γ energy (Lab) | > 1.5 GeV |
| • γ energy (Center of Mass) | > 20 MeV |
| • γ -track separation in CsI | > 30 cm |
| • Fusion χ^2 | < 48 |
| • γ CsI pipe block exclusion | smallring > 4.5 cm |
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| • $\pi^+ \pi^-$ invariant mass | < 0.492 GeV |
| • $\pi^+ \pi^- \gamma$ momentum | $25.0 < P_{\pi^+ \pi^- \gamma} < 160.0$ |
| • $\pi^+ \pi^- \gamma P_T^2$ | $< 2.5 \times 10^{-4}$ GeV ² |
| • $\pi^+ \pi^- \gamma$ invariant mass | $0.48967 < M_{\pi^+ \pi^- \gamma} < 0.50567$ |

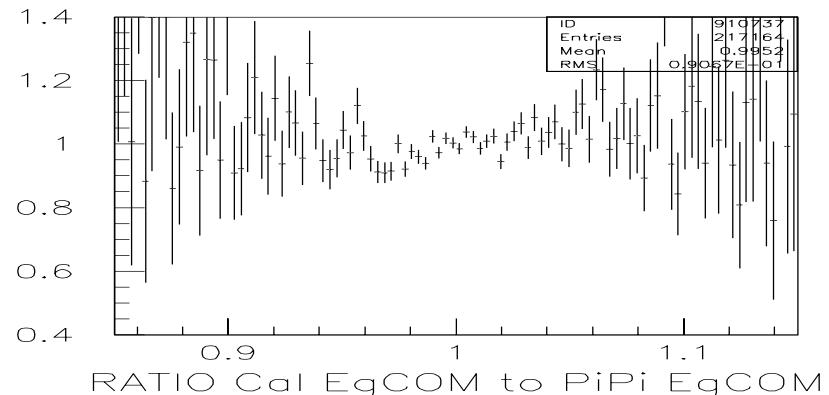
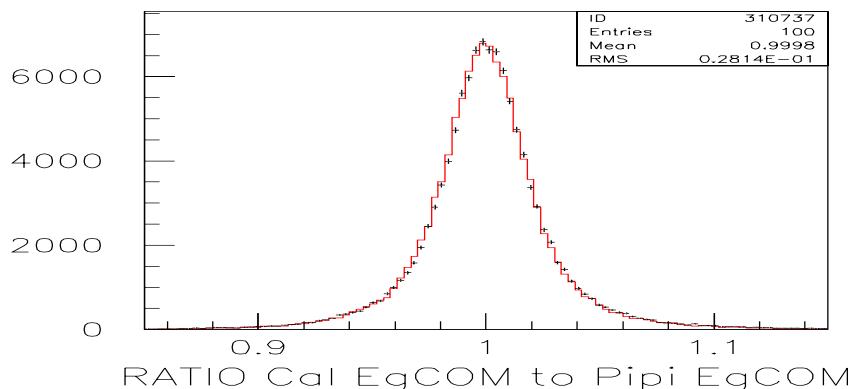
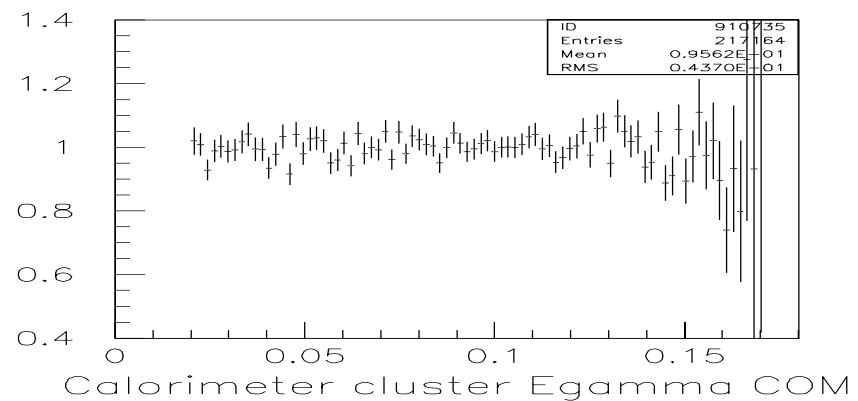
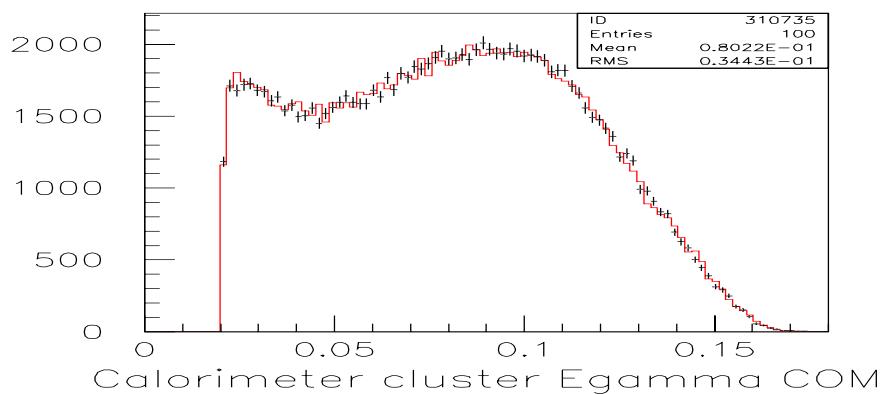
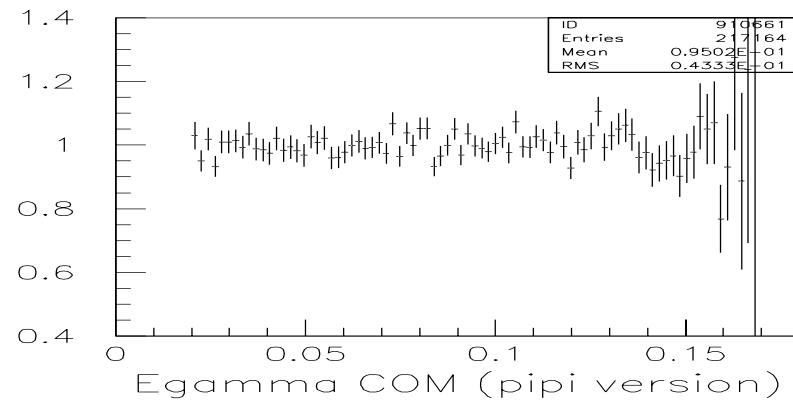
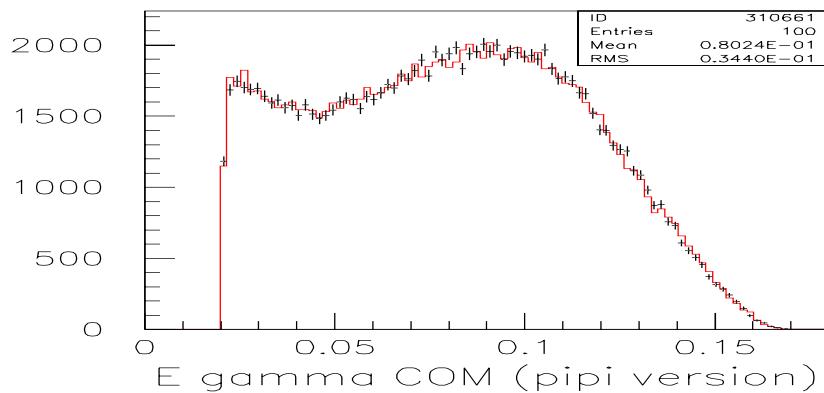
K_L → π⁺ π⁻ γ combined momentum (with reweighting)



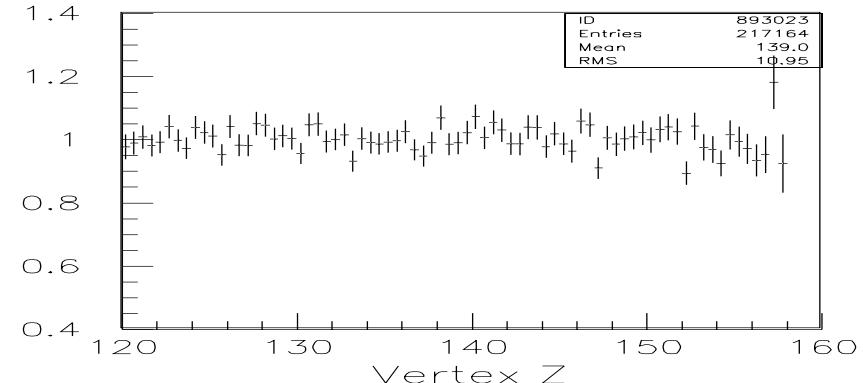
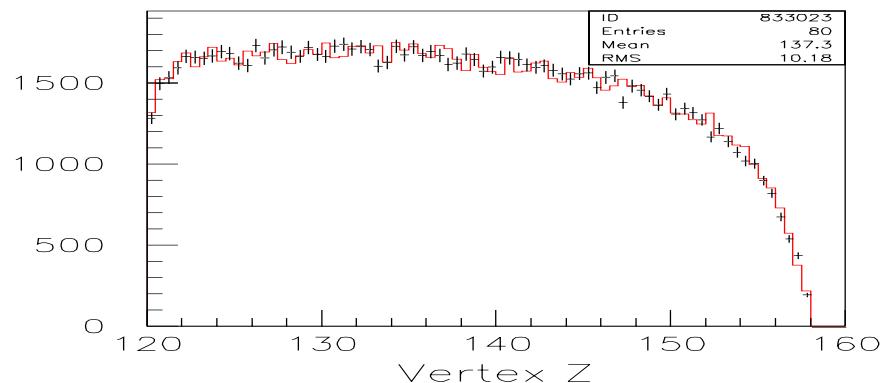
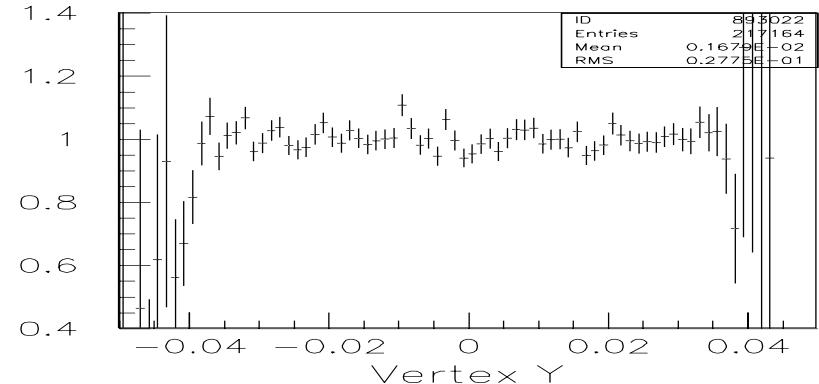
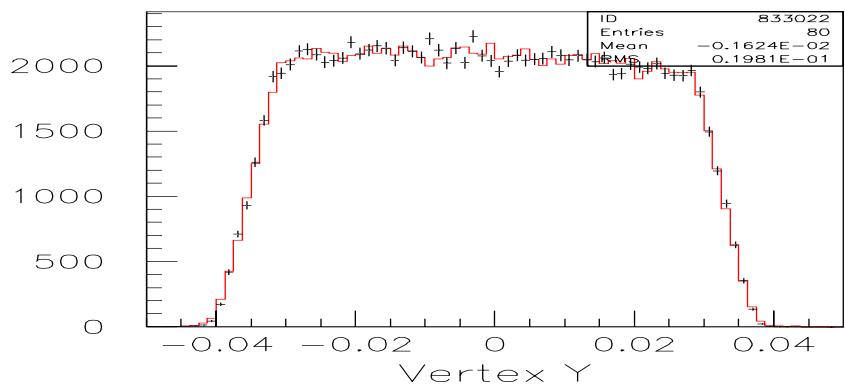
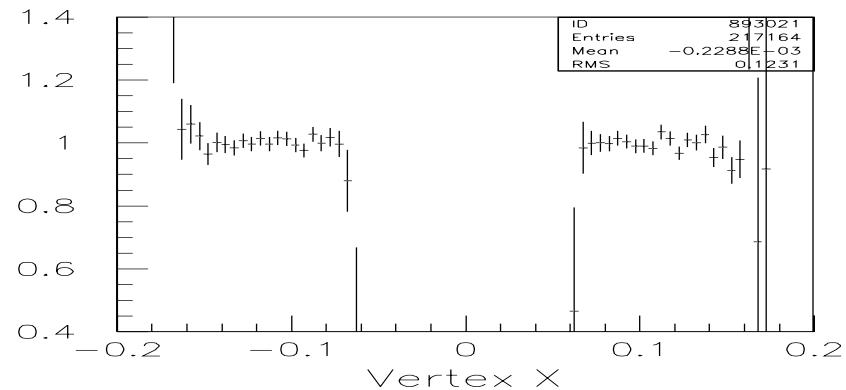
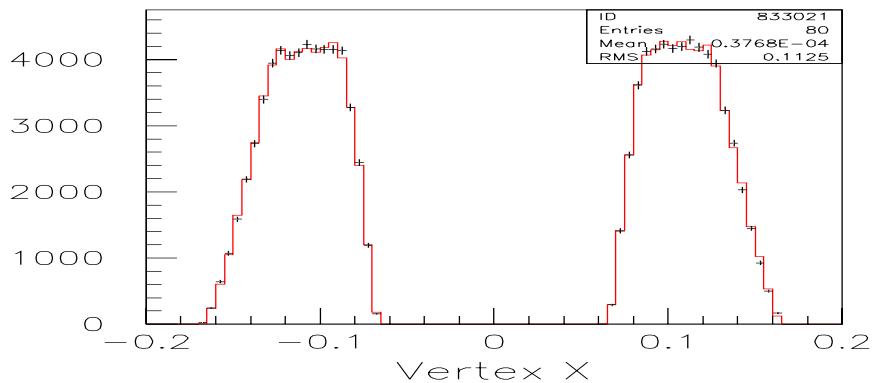
K_L → π⁺ π⁻ γ: Data / Monte Carlo



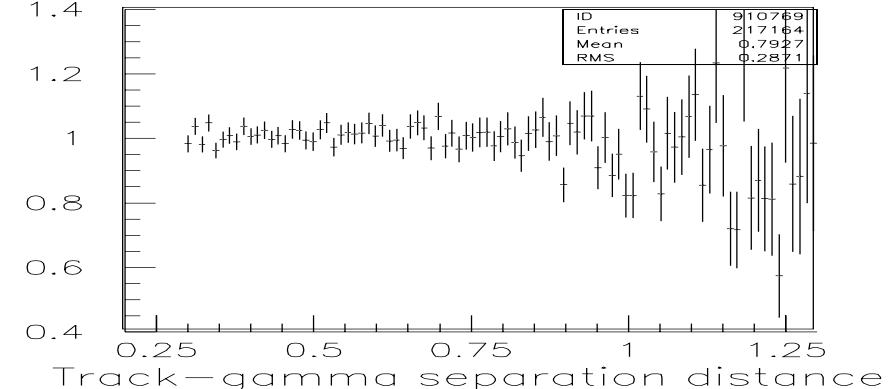
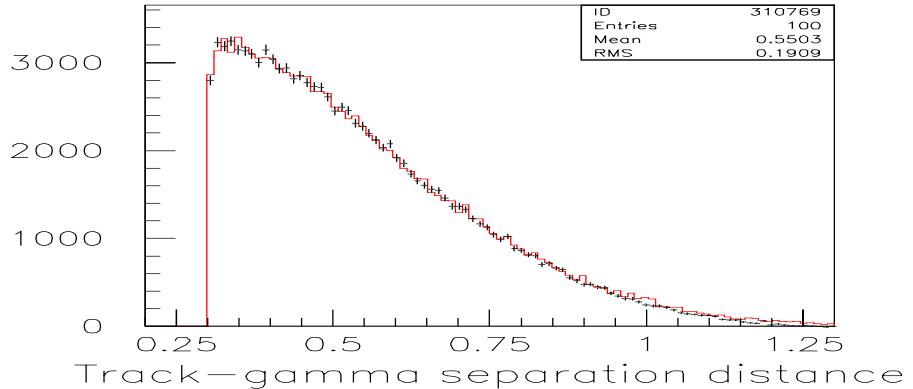
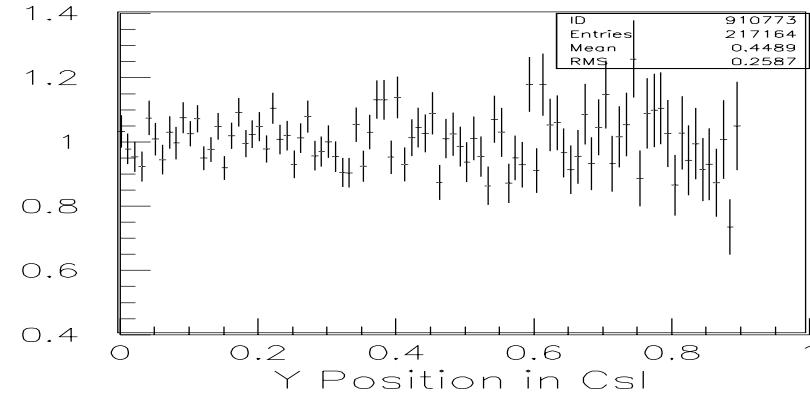
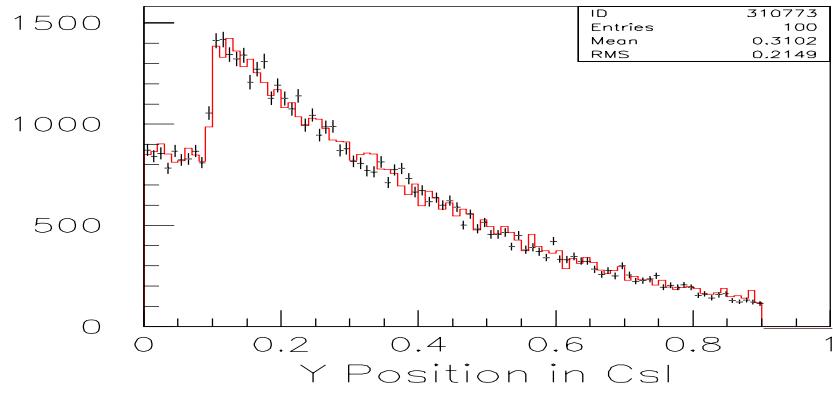
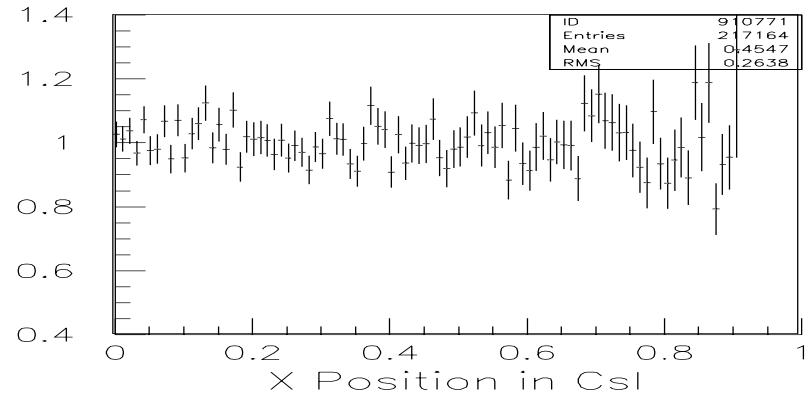
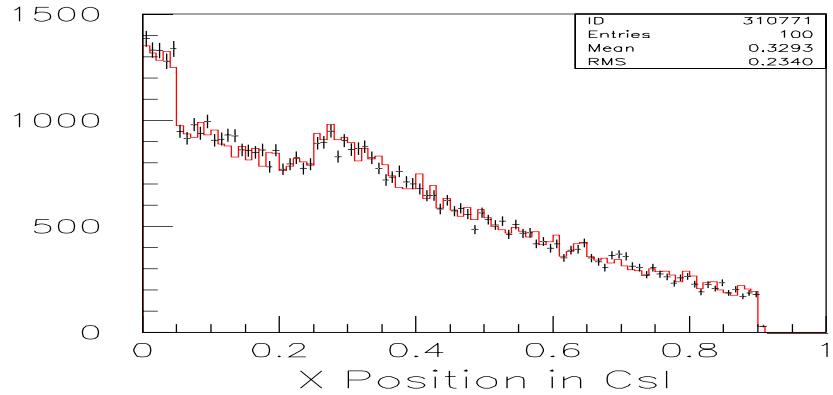
Two Independent Methods of Producing E_γ^* Distribution

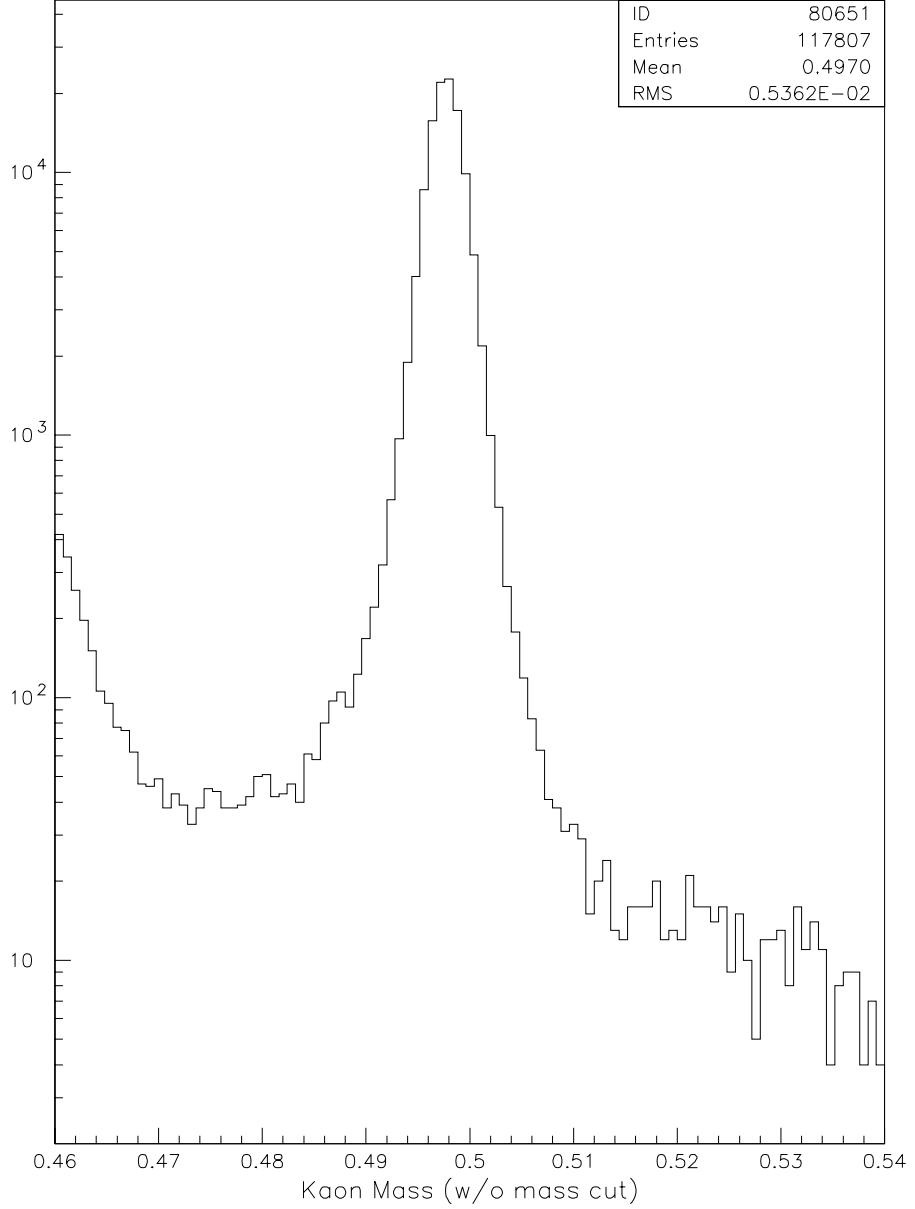
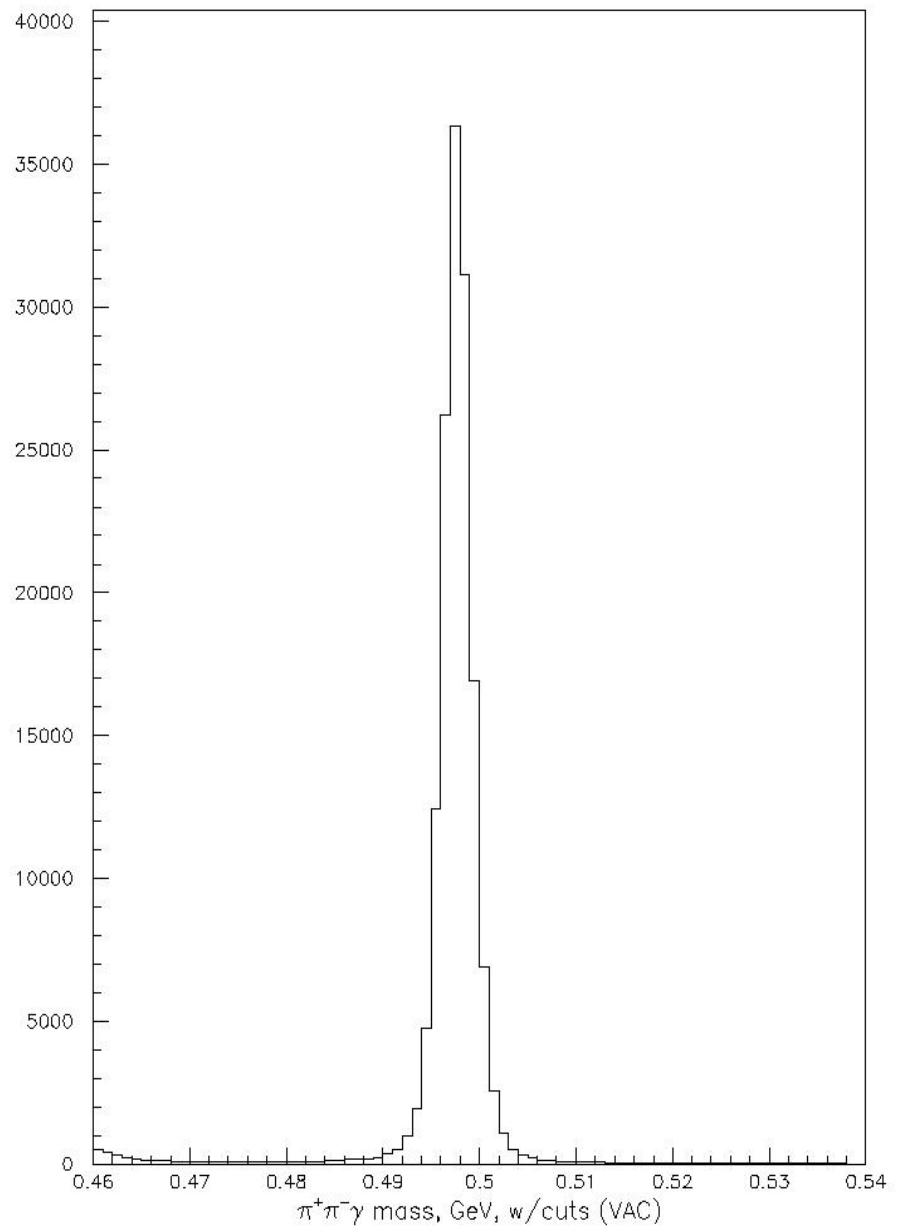


K_L→π⁺ π⁻ γ: Data / Monte Carlo



K_L→π⁺ π⁻ γ: Data / Monte Carlo





Future Plans: Tackle Systematics Studies

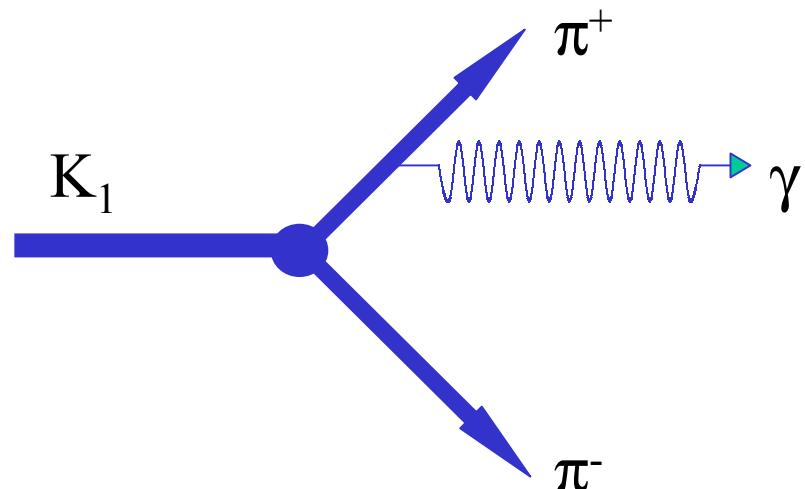
- Estimate of sources of greatest potential systematic error:
 - Background effects
 - Variation w.r.t run number
 - Uncertainty in matrix element model
 - $K_L \rightarrow \pi^+ \pi^- \gamma$ momentum resolution / CsI photon resolution
 - Cut variation
 - Z vertex
 - E_γ lab
 - Track - γ separation in CsI
 - Pp0kine
 - OTHER?????

Summary

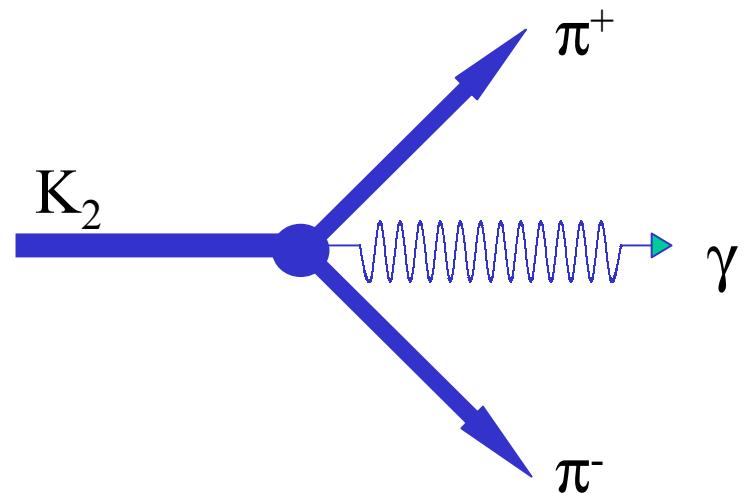
- Demonstrated a method of correcting $K_L \rightarrow \pi^+ \pi^- \gamma$ kaon momentum using $K_L \rightarrow \pi^+ \pi^- \pi^0$ background with one unreconstructed photon
- Preliminary $K_L \rightarrow \pi^+ \pi^- \gamma$ fit results (**STAT ONLY**)
 - $g_{m1} = 1.20 \pm 0.03$
 - $a1/a2 = -0.738 \pm 0.07$
 - $ge1 < 0.12$ (90% confidence)
 - Kaon momentum correction is still preliminary
 - Plan is to show these numbers at SESAPS conference (Nov, 2003)
- Future Plans:
 - Complete $K_L \rightarrow \pi^+ \pi^- \pi^0$ MC generation, kaon reweighting
 - Begin systematics studies
 - ** if anyone has systematics to add to my list, please let me know!!
 - GRADUATE: SPRING, 2004

(end of presentation)

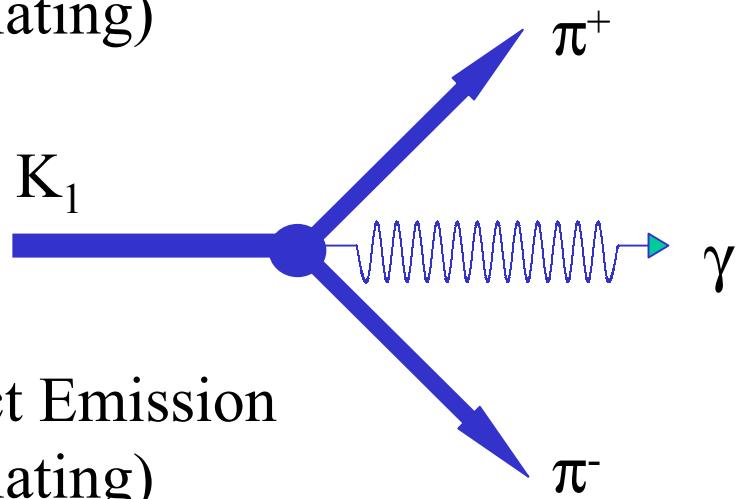
$K_L \rightarrow \pi^+ \pi^- \gamma$ Decay



Inner Bremsstrahlung
(CP Violating)



M1 Direct Emission
(CP conserving)



E1 Direct Emission
(CP Violating)

$K_L \rightarrow \pi^+ \pi^- \gamma$ Differential Decay Rate, Sehgal Model

$$\frac{d\Gamma}{d\omega d \cos\theta} = (const) \left[|\xi_E|^2 + |\xi_M|^2 \right] \omega^3 \beta^3 \left(1 - \frac{2\omega}{M_K} \right) \sin^2 \theta$$

where:

$$|\xi_E| = C_2 \left| \frac{\eta_{+-}}{\omega^2 (1 - \beta^2 \cos^2 \theta)} \right| + g_{e1}$$

$$|\xi_M| = \tilde{g}_{m1} \left[1 + \frac{a_1/a_2}{\left(M_\rho^2 - M_K^2 \right) + 2M_K E^* \gamma} \right]$$